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Offshore well leg internal cutting apparatus

Abstract:

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(54) Offshore well leg internal cutting apparatus

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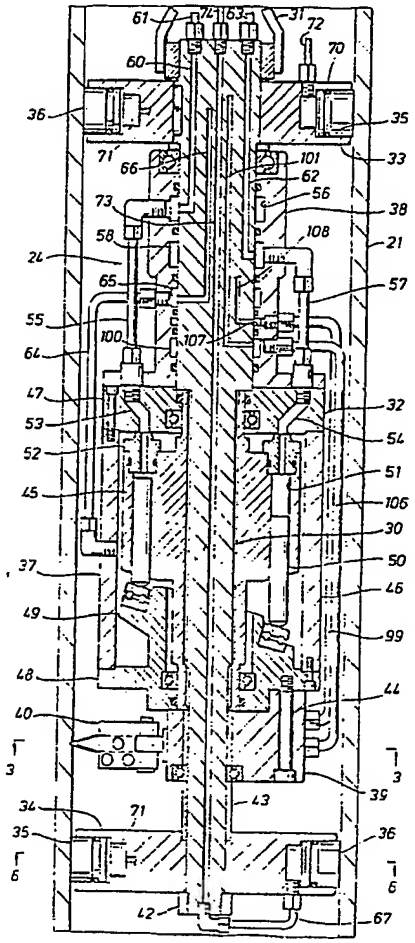

FIG. 2

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This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1982.

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FIG.1

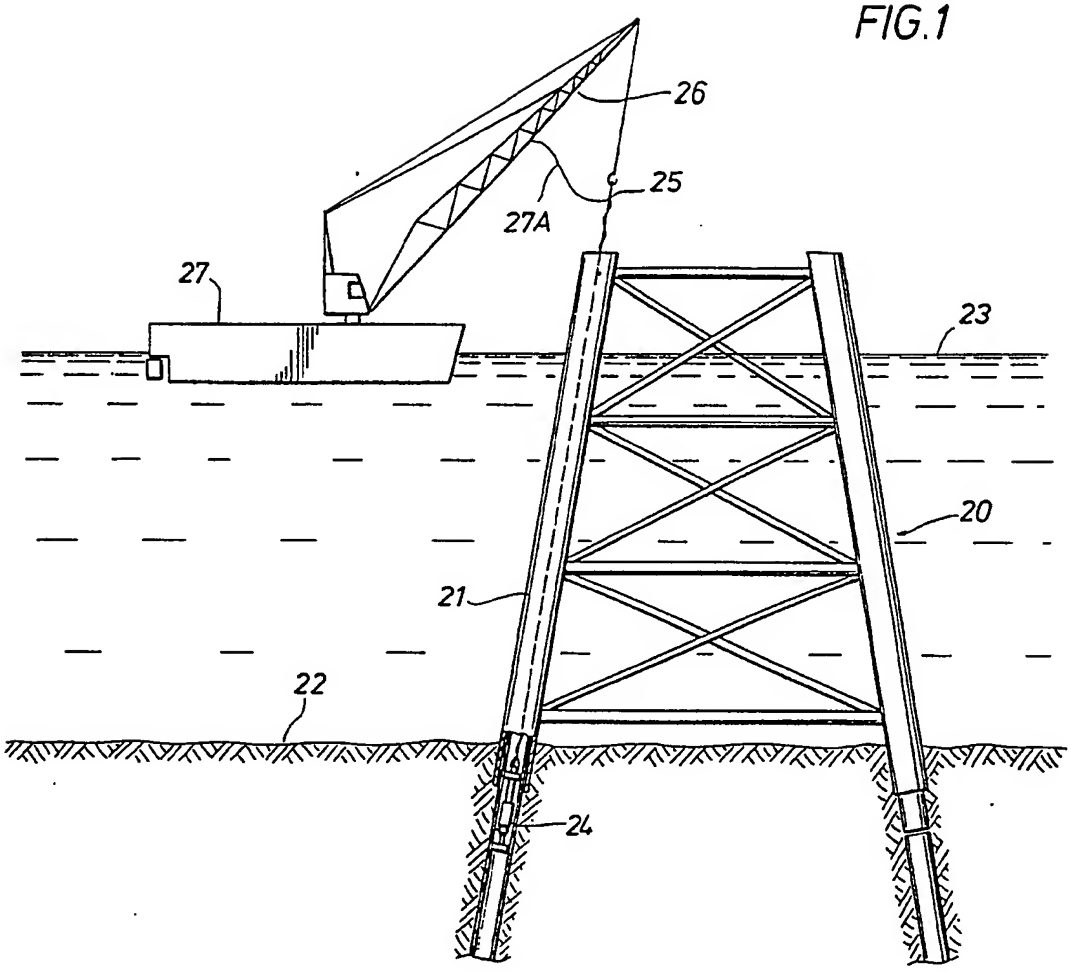

FIG.6

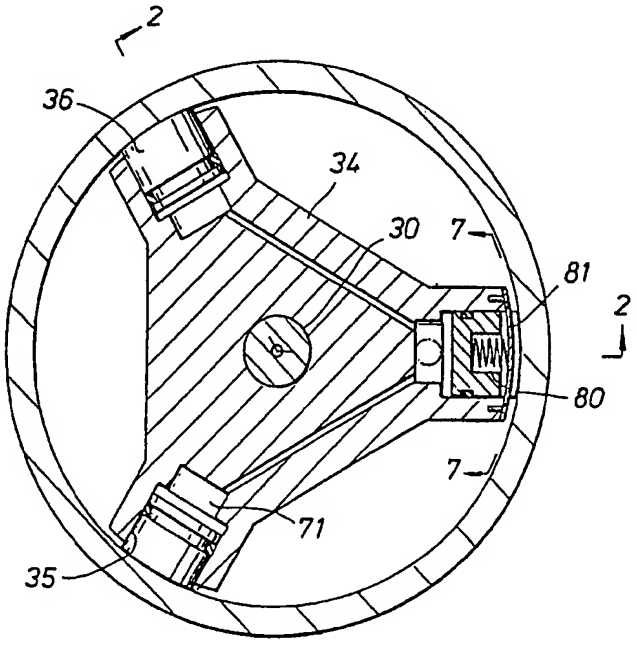

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FIG.2

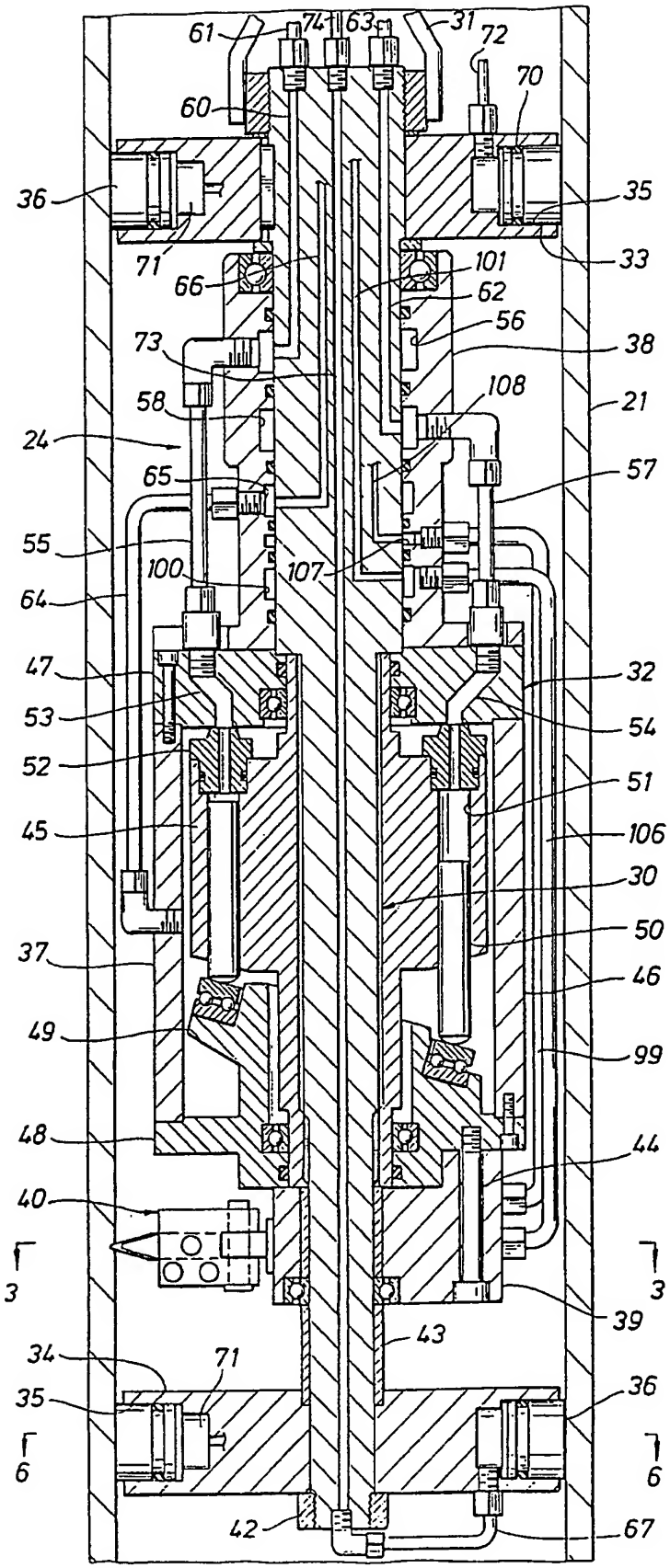

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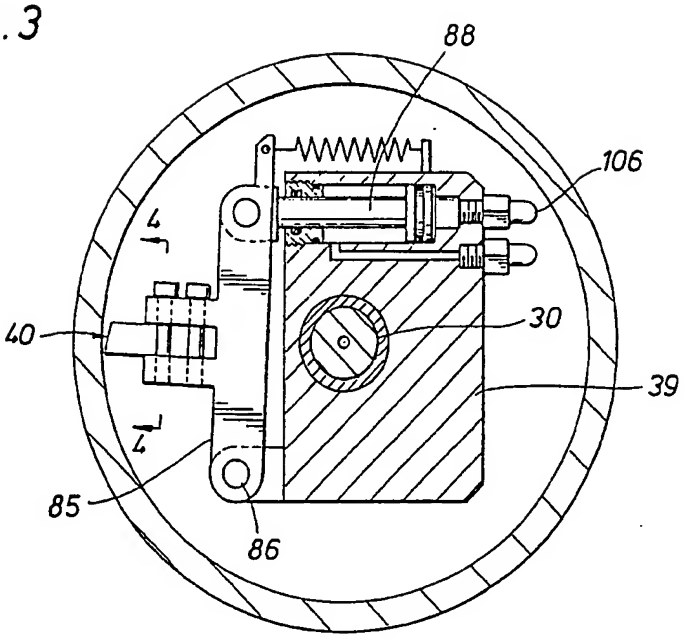
FIG. 3



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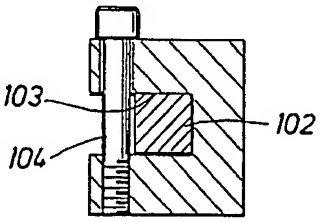

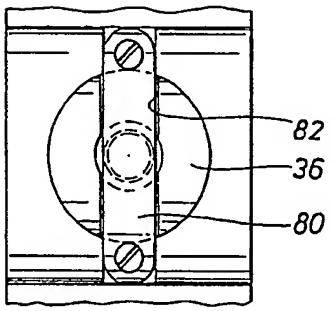

FIG. 7

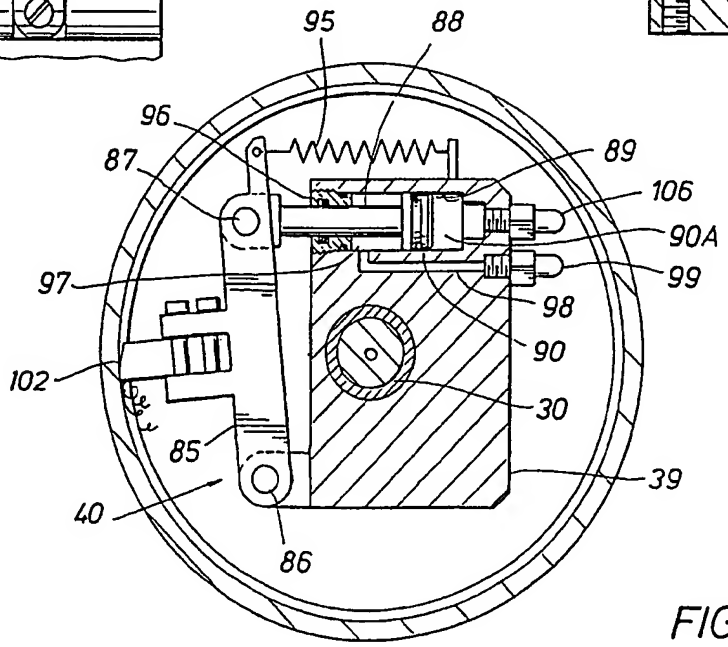

FIG. 5

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APPARATUS FOR USE IN SEVERING A TUBULAR MEMBER

This invention relates generally to apparatus for use in severing a tubular member which extends downwardly beneath the earth's surface. More particularly, it relates to improvements in apparatus of this type which may be lowered into the tubular member and which has cutting means adapted to be moved outwardly into cutting position with respect to the member and rotated with respect thereto, when so positioned, in order to sever the member, and which may be withdrawn to permit the apparatus to be raised from within the member. In one of its aspects, this invention relates to apparatus of this type which is particularly well suited to severing the hollow legs which are driven into the subsurface or below the mudline to support oil and gas production platforms at offshore locations.

In order to remove such a platform, it is necessary that its legs be severed a predetermined distance, usually at least sixteen feet, below the mud line, which in turn may be a substantial distance below the water level. In the past, it has been the practice to sever the legs by jetting or scouring out the mud or subsurface soil to the desired depth about the leg and then lowering a linear shaped charge over the leg and into the trench. When so lowered, the charge is detonated to sever the pipe and permit its upper end to be lifted to the water surface. However, the use of explosives violates environmental regulations, so that the industry must look to alternative means for severing the legs.

Well casings have heretofore been severed at substantial depths below the earth's surface by means of inside cutters comprising a body suspended from a pipe string extending to the surface and one or more arms pivotally mounted on the body for swinging about horizontal axes. Hydraulic fluid is supplied from the surface and through the pipe string to means within the body which, in response to the pressure of the fluid, swings the outer ends of the arms outwardly into tight engagement with the casing. The ends of the arms are provided with hard facing or other abrasive means so as to sever the casing as the body and arms are rotated with the pipe. When the casing is severed, rotation of the pipe and the supply of hydraulic fluid is discontinued to permit the arms to swing back to positions adjacent the body, and thus permit the cutter to be raised from the casing with the pipe string.

These cutters are inherently inefficient from a mechanical standpoint due to the acute angle at which their arms extend with respect to the horizontal as their outer ends are rotated while engaged with the casing. Also, cutting edges at the outer ends of the arms move upwardly as well as outwardly as they sever the casing, they must remove a large amount of metal from the casing, thus requiring considerable time and energy. Obviously, these problems would be amplified in the use of such a cutter in severing a platform leg which is of substantially larger diameter than the well casing.

The use of such an inside cutter is also time consuming since the individual joints of the pipe string must be made up and broken out as the cutter is lowered and raised within the casing. Furthermore, in order to hold the body of the cutter essentially centered, as the arms are moved out into engagement with the casing, a centralizer fits closely within the casing. Thus, the casing or other tubular member into which the cutter is lowered must be free of major obstructions, as may be encountered within platform legs.

An object of this invention is to provide apparatus which, like the above described inside cutter, may be lowered into a tubular member extending below the earth's surface, and then operated to sever the member by means of cutting means which are moved into cutting position relating to the member, in response to supply of power from the earth's surface, and then rotated, but which, as compared to the above described inside cutter, is highly efficient.

Another object is to provide such an apparatus which is of compact construction to permit it to be easily raised and lowered within the tubular member to be severed, and which is relatively inexpensive to manufacture and operate.

A further object is to provide such an apparatus which need not be lowered and raised on a pipe or centered within a tubular member by centralising elements carried by and lowered with the pipe, but rather may be raised and lowered on a cable and centered only when positioned at a level within the member at which it is to be severed.

The invention provides apparatus for use in severing a tubular member which extends substantially vertically below the earth's surface, comprising an elongate shaft adapted to be raised and lowered within the tubular member, holding means carried by the shaft for movement toward and away from the tubular member, means responsive to the supply of power from the surface level for moving said holding means into tight engagement with said tubular member in order to hold said shaft against movement with respect thereto, a body carried by the shaft for rotation thereabout, drive means on the body and shaft and responsive to the supply of power from the surface level for rotating said body about the shaft while said shaft is held against movement with respect to the tubular member, cutting means carried by the body for movement generally horizontally into and out of cutting position with respect to the tubular member, means responsive to the supply of power from surface level for

moving said cutting means into cutting position so as to sever the tubular member as the body is rotated about the shaft, said drive means being inoperable to rotate the body upon termination of the supply of power thereto, and means for withdrawing said holding means out of engagement with the tubular member and said cutting means out of cutting position, upon termination of the supply of power thereto, whereby the shaft may be raised from within the tubular member in order to retrieve the apparatus.

The illustrated embodiment of the invention comprise apparatus which comprises an elongate shaft adapted to be raised and lowered within the tubular member, holding means carried by the shaft for movement toward and away from the tubular member, and means responsive to the supply of power from the surface level for moving the holding means into tight engagement with the tubular member in order to hold the shaft against movement with respect thereto. A body is carried by the shaft for rotation thereabout, and a drive means on the body and shaft is responsive to the supply of power from the surface level for rotating the body about the shaft while the shaft is held against movement with respect to the tubular member. More particular, cutting means is carried by the body for movement generally horizontally into and out of engagement with the tubular member, and a means is provided for moving the cutting elements into tight engagement with the tubular member in response to the supply of power from the surface level so as to sever the tubular member as the body is rotated about the shaft. The drive means is inoperable to rotate the body upon termination of the supply of power thereto, and means are provided for withdrawing the holding means and the cutting means out of engagement with the tubular member upon termination of the supply of power thereto, whereby the shaft may be raised from within the tubular member in order to retrieve the apparatus.

Since in the illustrated embodiment the cutting means moves generally horizontally into engagement with

the tubular member, its cutting force is directed perpendicular with respect to the tubular member. This not only results in a highly efficient cutting operation, but also requires removal of only a minimum amount of metal from the member. Furthermore, since the shaft may be lowered on a cable and power, which, as illustrated, is hydraulic fluid, may be supplied to and exhausted from the operating parts of the apparatus through flexible conduits connecting with a source of the fluid at surface level, the apparatus requires neither a pipe string or centralising element.

As shown, the holding means includes a series of shoes which are carried in circumferentially spaced relation about the shaft, there preferably being a pair of series of shoes, one above and the other below the body. The cutting means, on the other hand, includes an arm carried by the body for pivoting about a generally vertical axis and means on its outer end for swinging therewith into and out of engagement with the tubular member.

As indicated above, each of the driving means and means for moving the holding means and cutting means into engagement with the tubular member is responsive to the supply of pressure fluid through conduits connecting with a source of such fluid at surface level, although, in its broader aspects, this invention anticipates that one or more of such parts of the apparatus may respond to electrical power. Preferably, and as shown, the conduits connect with passageways formed in the shaft, as well as passageways formed in the body. More particularly, the passageways in the shaft and body connect with oppositely facing annular surfaces thereof which carry seal means confining the flow of power fluid between the passageways during rotation of the body.

The shaft includes means which provides outwardly opening cylinders in which the shoes are sealably reciprocal, and the means for moving the shoes includes conduits connecting with the cylinders inwardly of the shoes. The means for withdrawing the shoes includes a

spring means arranged to urge each shoe toward its inner position.

In continuing reference to the illustrated embodiment described here fully below, the means for moving the cutting means into engagement with the tubular member includes means forming a cylinder in the body, and a piston sealably reciprocable in the cylinder and having a rod extending from the cylinder to connect with the arm. The drive means, on the other hand, includes a motor having cylinder means in one of the body and shaft, piston means sealably reciprocable within the cylinder means, and means connecting the piston means and the other of the body and shaft to rotate such body in response to reciprocation of the piston means. Preferably, the cylinder means extends in a generally vertical direction parallel to the axis of the shaft, so that the motor occupies a minimum lateral dimension within the tubular member.

In the drawings, wherein like reference characters are used throughout to indicate like parts;

Figure 1 is a diagrammatic illustration of the legs of an offshore platform and apparatus constructed in accordance with the present invention lowered into one of the legs for severing it at a predetermined distance beneath the mud line;

Figure 2 is a vertical sectional view of the apparatus with its shoes moved outwardly to hold the shaft in a fixed position within the leg and the outer ends of the arms,

moved outwardly into tight engagement with the tubular member;

Fig. 3 is a cross-sectional view of the apparatus, as seen along broken lines 3-3 of Fig. 2;

Fig. 4 is an enlarged cross-sectional view of a portion of the cutting arm, as seen along broken lines 4-4 of Fig. 3;

Fig. 5 is another cross-sectional view of the apparatus, similar to Fig. 3, but during rotation of the cutting arm while engaged with the tubular member in order to form a cut about its inner surface;

Fig. 6 is a cross-sectional view of the apparatus, as shown along broken lines 6-6 of Fig. 2, and

Fig. 7 is an enlarged detail view of the outer end of one of the shoes shown in Fig. 6 as seen along broken lines 7-7 of Fig. 6.

With reference now to the details of the above described drawings, the offshore platform 20 shown in Fig. 1 includes a plurality of hollow, upright legs 21 whose lower ends have been driven into the subsurface level or mud line 22 and whose upper ends extend above the water level 23 to support a deck (not shown). As previously described, environmental regulations require that these legs be severed a predetermined distance beneath the mud line, and, for this purpose, apparatus constructed in accordance with the present invention, and indicated in its entirety by reference character 24, has been lowered into a desired level within one of the legs by means of a cable 25 suspended from a boom 26 supported on a vessel 27 adjacent the platform. As will be understood, the boom includes a reel which enables the cable and thus the apparatus 24 to be raised and lowered.

As shown in Fig. 2, the apparatus 24 includes an elongate shaft 30 having a bail 31 at its upper end for connection to the lower end of the cable 25 and a body 32 which surrounds the shaft for rotation with respect thereto. The shaft includes radially enlarged portions 33 and 34 at

its upper and lower ends above and below the body 32, each having three outwardly opening cylinders 35 formed therein in equally circumferentially spaced relation. More particularly, a shoe 36 is reciprocably mounted within each cylinder for movement between inner and outer positions for selectively holding the shaft in or releasing it from a fixed position within the leg, as will be described to follow. As shown, the outer diameters of the shaft portions 33 and 34 fit relatively closely within the tubular member so as to maintain the apparatus in a generally centered position as it is raised and lowered within the tubular member, and thus minimize the distance which the shoes must travel between their inner and outer positions.

The rotatable body 32 includes a central motor housing 37 disposed about an intermediate portion of the shaft, an upper tubular portion 38 which connects fluid passageways in the shaft with fluid passageways in the body during rotation of the body with respect to the shaft, and a lower housing 39 on which cutting means 40 is carried for movement between inner and outer positions, as will also be described to follow. As shown in Fig. 2, the lower shaft portion 34 is supported on the lower end of the shaft by means of a nut 42, and the lower end of the cutter housing is supported for rotation about the shaft thereabove by means of a spacer sleeve 43. The motor housing 37 is in turn supported above the cutter housing and connected thereto for rotation therewith by one or more bolts 44. The upper tubular part 38 of the body is supported above and rotatable with the motor housing, and the upper shaft portion is supported by the upper end of the tubular part beneath the connection of the bail to the shaft.

The drive means or motor of the apparatus includes a body 45 which is splined to the intermediate portion of the shaft 30 so as to be held against rotation with respect to it, and which is disposed within the motor housing 37 of the body of the apparatus. The motor housing 37 includes an intermediate cylindrical wall 46 and upper and lower end

walls 47 and 48 which are bolted or otherwise secured to the intermediate wall above and below the body portion 45 of the shaft.

The motor includes an inclined plate 49 which is mounted on the upper side of the bottom wall 48 and which carries a bearing on its upper side beneath pistons 50 which are mounted for vertical reciprocation within cylinders 51 formed in circumferentially spaced apart relation about the body portion 45 of the shaft. Thus, as will be more fully understood from the description to follow, the supply of hydraulic fluid to the upper ends of the piston applies force to the inclined plate to cause it and thus the motor housing, and consequently the remainder of the body of the apparatus connected thereto including the cutting means 40, to rotate about the shaft.

For this latter purpose, a plug 52 having a port therethrough is received in the upper enlarged end of each cylinder 51 with its upper end disposed adjacent the lower side of the upper wall 47 of the motor housing. The motor housing is in turn provided with passageways 53 and 54 which connect respectively with the ports within the plugs 52 leading to the pistons on opposite sides of the body 45. The passageways 53 and 54 have arcuate slots in their lower ends which connect with the ports in the upper ends of the plugs during rotation of the housing with respect to the shaft, and through which hydraulic fluid may be respectively supplied and exhausted by means of passageways in the body and shaft connecting with conduits leading to the surface level. More particularly, the conduits lead to a source of hydraulic fluid which may be installed on the vessel 27 and connected to a bundle 27A of the conduits for lowering with the apparatus into the tubular member to be severed.

A so-called "hollow shaft" hydraulic motor of the type above described is manufactured and sold by North American Hydraulics, Inc. of Baton Rouge, Louisiana. Although a low speed, high torque motor of this type is believed to be especially well suited for rotating the body of the

apparatus with respect to the shaft, it will be understood that other hydraulic motors, or for that matter motors adapted to be responsive to electrical power source at the surface level, may also be used.

As shown in Fig. 2, passageway 53 is connected to a pipe 55 having an elbow at its upper end to connect it with an annular recess 56 about the inner diameter of tubular portion 38 of the body. The upper end of the passageway 54, on the other hand, is connected to a pipe 57 having an elbow at its upper end connecting it with an annular recess 58 about the inner diameter of the body portion 38 beneath the recess 56. The recess 56 is disposed opposite a passageway 60 formed vertically within the shaft and connected at its upper end to a conduit 61 extending downwardly from the surface level, and the recess 58 is disposed opposite the lower end of a passageway 62 in the shaft connecting at its upper end to a conduit 63 also leading to the surface level. Thus, as indicated above, hydraulic fluid may be supplied to the passageways leading to the upper ends of the left hand pistons, while being exhausted from the upper ends of the right hand pistons shown in Fig. 2 so as to transmit the downward linear force of the pistons to the plate 49 in order to cause the plate and thus the entire body of the apparatus to rotate. As the body is rotated to a position in which the left hand pistons are in the lower positions, the arcuate lower end of the passageway 53 is disposed over the ports in the plugs in the upper ends of the right hand pistons, while the arcuate slot in the lower end of passageway 54 is disposed above the ports in the plugs above the left hand pistons, thereby causing the just raised pistons to be lowered in order to continue rotation of the body in response to the continuing supply and exhaust of hydraulic fluid.

Hydraulic fluid which leaks from between the passageways 53 and 54 and the upper ends of the plugs 52 is collected within the motor housing and withdrawn through a pipe 64 connecting at its upper end with another annular

recess 65 about the inner diameter of the tubular member 38 below the recess 58. This recess is opposite still another passageway 66 which is formed in the shaft and which connects at its upper end to another conduit (not shown) leading to the surface level, which conduit may be connected to suitable apparatus on the vessel for suctioning the excess hydraulic fluid from within the motor housing.

As shown, each of the shoes 36 carries a seal ring about its outer diameter to form a pressure chamber 71 within the inner end of the cylinder to which hydraulic fluid may be supplied or through which fluid may be exhausted. A conduit 72 leads from the pressure chambers behind the upper shoes to a valve controlled pump at surface level for alternately supplying hydraulic fluid to or exhausting it from the pressure chambers. As shown, the hydraulic fluid from the same pump at surface level is also alternately supplied to and exhausted from pressure chambers 71 in the cylinders behind the lower shoes by means of a passageway 73 formed in the shaft and connecting at its upper end with a conduit 74 and its lower end with a pipe 67 connecting to the chambers.

When the hydraulic fluid is exhausted from the pressure chambers 71, each of the shoes is automatically withdrawn to their inner positions by means of a spring 80 which, as shown in Fig. 6, is compressed between a recess in the outer end of each shoe and a metal strap 81 which is mounted on the shaft within a slot 82 across the nose of the shoe so as to prevent the shoe from falling out of the cylinder.

As shown in Figs. 3, 4 and 5, the cutting means 40 comprises an arm 85 which is mounted on the cutter housing 39 by means of a vertically extending pivot pin 86 so as to swing horizontally between inner and outer positions. The arm is connected by a pivot pin 87 at its opposite end to the outer end of a rod 88 extending from a piston 90 reciprocable within a cylinder 89 in the cutter housing. Thus, upon extension of the rod, a cutting element 102 on the arm is forced into tight engagement with the tubular

member, as shown in Fig. 5, so as to cut a groove about the inner diameter of the tubular member as the body of the apparatus and thus the cutter housing is rotated. On the other hand, upon retraction of the rod, the cutting element is withdrawn from the tubular member so as to permit it to be raised and lowered with respect thereto.

The rod is urged outwardly by means of hydraulic fluid supplied to a pressure chamber 90A on the inner side of the piston so as to move the cutting element into tight engagement with the tubular member, whereby, upon rotation of the body of the apparatus with respect to the shaft, the cutting element will progressively cut the inner diameter of the tubular member in order to sever it. Fluid is so supplied to the chamber by means of a pipe 106 connecting at its upper end with an annular recess 100 about the inner diameter of tubular part 38 opposite the lower end of a passageway 101 in the shaft leading to a flexible conduit (not shown) extending to a source of hydraulic fluid at the earth's surface.

A spring 95 is connected between the outer end of the arm and the cutter housing so as to yieldably urge the cutting element toward the inner position of Fig. 3 in which the apparatus is free to move vertically within the tubular member. Preferably, however, and as shown in the drawings, the piston and thus the rod connected to the arm are adapted to be positively moved toward their inner position by means of hydraulic fluid from a source at surface level. For this purpose, the outer end of the cylinder 89 is closed by means of a wall 96 to form a pressure chamber 97 between the wall and the outer side of the piston. A passageway 98 in the cutter housing in turn connects with a pipe 99 leading upwardly to still another annular recess 107 formed about the inner diameter of the tubular portion 38. The last mentioned recess is in turn disposed opposite the lower end of a further passageway 108 formed in the shaft and adapted to connect at its upper end with still another conduit (not shown) leading to the surface level for connection with a

source of hydraulic fluid at the earth's surface. More particularly, the two conduits connecting with the passageways 101 and 108 may connect with a pilot valve with a common source of hydraulic fluid for selectively moving the cutting element toward or away from cutting position may be connected with a suitable reversing valve of a pump for moving the cutting element between its inner and outer positions in a selected manner.

As shown, the cutting element 102 may comprise a replaceable bit releasably held within a slot 103 in an outer projection on the arm 89 by means of bolts 104.

Considering now the overall manner in which a leg is severed, the apparatus is first lowered on cable 25 to the desired level therein, with the cutting element withdrawn by the spring 95, and possibly by the hydraulic fluid supplied to the outer side of piston 90. Hydraulic fluid is then supplied to the pressure chambers 71 behind both sets of shoes to force then outwardly into tight engagement with the leg and thereby hold the shaft 30 against vertical or rotary movement. At this time, hydraulic fluid is supplied and exhausted through passageways 53 and 54 in order to rotate the body about the shaft, and is supplied and exhausted through passageways 101 and 108 to force the cutting element tightly against the leg. Of course, if the cutting element was withdrawn by hydraulic fluid from the same source, the pilot valve connecting with that source would first be moved to its alternate position to exhaust hydraulic fluid from the inner side of the piston as it is supplied to the outer side thereof.

Rotation of the body is continued until the cutting element cuts entirely through the leg, at which time the supply of hydraulic fluid to the motor is discontinued to permit the body to stop rotation, and the supply of hydraulic fluid to the piston is reversed to withdraw the cutting element. At this time, the supply of hydraulic fluid to the shoes may also be discontinued to permit them

to be retracted by the springs 80, thereby freeing the apparatus for retrieval.

The drawings illustrate only one preferred embodiment of the invention. In an alternative form, the cutting means described could be replaced by an acetylene torch or the like.

CLAIMS

1. Apparatus for use in severing a tubular member which extends substantially vertically below the earth's surface, comprising

an elongate shaft adapted to be raised and lowered within the tubular member,

holding means carried by the shaft for movement toward and away from the tubular member,

means responsive to the supply of power from the surface level for moving said holding means into tight engagement with said tubular member in order to hold said shaft against movement with respect thereto,

a body carried by the shaft for rotation thereabout,

drive means on the body and shaft and responsive to the supply of power from the surface level for rotating said body about the shaft while said shaft is held against movement with respect to the tubular member,

cutting means carried by the body for movement generally horizontally into and out of cutting position with respect to the tubular member,

means responsive to the supply of power from surface level for moving said cutting means into cutting position so as to sever the tubular member as the body is rotated about the shaft,

said drive means being inoperable to rotate the body upon termination of the supply of power thereto, and

means for withdrawing said holding means out of engagement with the tubular member and said cutting means out of cutting position, upon termination of the supply

of power thereto, whereby the shaft may be raised from within the tubular member in order to retrieve the apparatus.

2. Apparatus as described in Claim 1, wherein

said holding means includes a series of shoes carried in circumferentially spaced relation about the shaft.

3. Apparatus as described in claim 2, wherein there are a pair of series of shoes, one above and the other below said body.

4. Apparatus as described in claim 1, wherein the cutting means includes an arm carried by the body for pivoting about a generally vertical axis, and a cutter element carried by the arm for swinging therewith into and out of engagement with the tubular member.

5. Apparatus as described in claim 1, wherein each of the driving means and the means for moving the holding means and cutting means is responsive to the supply of pressure fluid through conduits connecting with a source of such fluid at surface level.

6. Apparatus as described in claim 5, wherein said conduits include passageways formed in the shaft.

7. Apparatus as described in claim 6, wherein the conduits also include passageways formed in the body.

8. Apparatus as described in claim 7, wherein the passageways in the shaft and body connect with oppositely facing annular surfaces thereof which carry seal means confining the flow of pressure fluid between the passageways during rotation of the body.

9. Apparatus as described in claim 5, wherein said holding means includes a series of shoes carried in circumferentially spaced relation about the shaft.

10. Apparatus as described in claim 9, wherein said shaft includes means providing a series of outwardly opening cylinders in which the shoes are sealably reciprocable, and

said means for moving said shoes includes conduits connecting with said cylinders inwardly of the shoes.

11. Apparatus as described in claim 9, wherein said means for withdrawing said shoes includes spring means urging each shoe toward its inner position.

12. Apparatus as described in claim 5, wherein the cutting means includes an arm carried by the body for pivoting about a generally vertical axis.

13. Apparatus as described in claim 12, wherein said means for moving said cutting means includes means forming a cylinder in the body,

a piston sealably reciprocable in the cylinder and having a rod extending from the cylinder to connect with the arm.

14. Apparatus as described in claim 5, wherein the drive means includes cylinder means in one of the body and shaft,

piston means sealably reciprocable in the cylinder means, and

means connecting the piston means and the other of the body and shaft to rotate said body in response to reciprocation of the piston means.

15. Apparatus for use in severing a tubular member substantially as herein described with reference to the accompanying drawings.

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